8.2 MECHANICAL EQUIPMENT

8.2.1 FLUID-OPERATED / *AIR-OPERATED* VALVES[1]

The seismic capacity for the equipment class of Fluid-Operated Valves (FOV) *and Air-Operated Valves (AOV) (see Figure 8.2.1-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes a wide diversity of valve sizes, types, and applications, which are actuated by air, water, or oil. Liquid-operated (i.e., hydraulic) piston valves are not included in the FOV class of equipment because they have not been reviewed in sufficient detail to be included.

The main types of fluid-operated valves are diaphragm-operated, piston-operated, and pressure relief valves. The most common type of fluid-operated valve found in facility applications is a spring-opposed, diaphragm-operated pneumatic valve. The bell housing contains a diaphragm (usually a thin, steel membrane) which forms a pressure barrier between the top and bottom sections of the housing. The position of the actuated rod (or valve stem) is controlled by a return spring and the differential pressure across the diaphragm. The actuated rod position, in turn, controls the position of the valve. A yoke supports the bell housing and connects it to the valve body. A solenoid valve or, on larger valves, a pneumatic relay controls the air pressure difference across the diaphragm. This solenoid valve or pneumatic relay is often mounted directly to the operator yoke.

Piston-operated valves are similar to diaphragm-operated valves, with a piston replacing the diaphragm as the valve actuator. The piston typically acts in opposition to a spring to control the position of the valve.

Pressure relief valves are also included in this equipment class. Pressure relief valves balance confined fluid pressure against the force of a spring. The actuating force in a pressure relief valve is supplied by the fluid that is confined by the valve. Fluid-operators are typically cantilevered either above or to the side of the valves they serve. The valve and actuator can form a continuous body, or the actuator can be attached to the valve through a flanged, threaded, or ring clamp connection.

The valve, the operator, *the inlet and outlet lines up to their first support on the building or nearby structure,* and peripheral attachments (air lines, pneumatic relays, control solenoids, and conduit) are included in the Fluid-Operated Valve equipment class. The valve may be of any type, size, or orientation.

8.2.1.1 *Reference Spectrum Caveats - Fluid-Operated Valves*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Fluid-Operated Valve (FOV) if the valve meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

FOV/*RS* Caveat 1 - Earthquake Experience Equipment Class. The valve should be similar to and bounded by the FOV class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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[1] Section B.7 of SQUG GIP (Ref. 1)

FOV/*RS* Caveat 2 - Valve Body Not of Cast Iron. The valve body should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. It is not necessary to determine the material of the valve body unless it appears to the *SCEs* that the body is made of cast iron. It is suggested that the material of a flanged valve be checked. In such cases, if the valve is indeed cast iron, the intent of this caveat is satisfied if seismic stresses in the valve body due to piping loads are low (for example, less than 20% of specified minimum ultimate tensile strength).

FOV/*RS* Caveat 3 - Valve Yoke Not of Cast Iron for Piston-Operated Valves and Spring-Operated Pressure Relief Valves. The yoke of piston-operated valves and spring-operated pressure relief valves should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. It is not necessary to determine the material of the valve yoke unless it appears to the *SCEs* that the yoke is made of cast iron. In such cases, if the yoke is indeed cast iron, this caveat may be satisfied by performing a stress analysis of the valve for a 3g load applied at the center of gravity of the operator in the yoke's weakest direction. If the yoke stress is low (for example, less than 20% of specified minimum ultimate strength), then the intent of the caveat is satisfied.

FOV/*RS* Caveat 4 - Mounted on 1-Inch Diameter Pipe Line or Greater. The valve should be mounted on a pipe line of at least 1-inch diameter. This is the lower bound pipe size supporting FOVs in the earthquake experience equipment class. The concern is that valves with heavy operators on small lines may cause an overstressed condition in the adjacent piping. To satisfy the intent of this caveat a stress analysis (that accounts for the valve operator eccentricity) may be used to show that the pipe stress adjacent to the valve is low. There is no concern if the valve, the operator, and the line (if smaller than 1 inch) are well-supported and anchored to the same support structure.

FOV/*RS* Caveat 5 - Valve Operator Cantilever Length for Air-Operated Diaphragm Valves, Spring-Operated Pressure Relief Valves, and Light Weight Piston-Operated Valves. The distance from the centerline of the pipe to the top of the operator or cylinder should not exceed the distance given in Figure *8.2.1-2* corresponding to the diameter of the pipe. This figure bounds the pipe diameter and operator length combinations included in the earthquake experience equipment class. The concern is that longer operator lengths may lead to excessive valve yoke stress.

As a second screen to evaluate the operator weight and length, Figure *8.2.1-3* may be used instead of the limits given in Figure *8.2.1-2* provided: (1) the yoke is not of cast iron (Caveat 3 applies), and (2) the operator length does not exceed about 30% beyond the limits of Figure *8.2.1-2*.

As a third option, this caveat may also be satisfied by performing a stress analysis consisting of applying a 3g load at the center of gravity of the operator in the yoke's weakest direction. If the yoke stresses are low and the relative deflections are small (to ensure that shaft binding will not occur) then the caveat is satisfied.

Alternately, an in-situ static test may be conducted to demonstrate seismic adequacy. In these tests, a static force equal to three times the operator weight should be applied approximately at the center of gravity of the operator, in each of the three orthogonal principal axes of the yoke (non-concurrently). Such tests should include demonstration of operability, i.e., the valve can open and close, following the application of the static loads. Note that all of the other limitations still apply.

A mockup test stand may be used provided that the details are similar to those in the *facility*. If there are numerous valves, a rational test program may be developed to envelop the valve configurations in the *facility*.

FOV/*R*S Caveat 6 - Valve Operator Cantilever Length for Substantial Piston-Operated Valves. For piston-operated valves which are of substantial weight, the distance from the centerline of the pipe to the top of the operator or cylinder and the weight of the operator should not exceed the values given in Figure *8.2.1-3* corresponding to the diameter of the pipe. This figure represents the pipe diameter and operator weight/length combinations included in the earthquake experience equipment class. The concern is that longer operator lengths or heavier operator weights may lead to excessive valve yoke stress.

To meet the intent of this caveat the operator length or weight may be extrapolated by as much as 30% beyond that given in Figure *8.2.1-3* provided the product of the weight times the lever arm does not exceed the limits of Figure *8.2.1-3*.

If the ground motion spectra for the site is below the *Reference* Spectrum, over the entire frequency range possible for the piping and valve network, the operator weight or distance to the top of the operator can be increased by the ratio of the spectra. The cantilever length or the operator weight should not be increased by more than about 30% beyond the limits of Figure *8.2.1-3*.

Another option for satisfying this caveat is to perform a stress analysis that consists of applying a 3g load at the center of gravity of the operator in the yoke's weakest direction. If the yoke stresses are low and the relative deflections are small (to ensure that shaft binding will not occur) then the caveat is satisfied. Alternately, as discussed in FOV/*R*S Caveat 5 above, a static test may be performed.

FOV/*R*S Caveat 7 - Actuator and Yoke Not Independently Braced. The valve actuator and yoke should not be independently braced to the structure or supported by the structure unless the pipe is also braced to the same structure immediately adjacent to the valve. The concern is that if the operator is independently supported from the valve and attached piping, then the operator may act as a pipe support during seismic motion and attract considerable load through the yoke and possibly fail the yoke or bind the shaft. In addition, if both the operator and the valve/pipe are restrained, and if they are both not tied back to the same structure, then differential motion of support points may lead to high seismic loads and possible binding of the shaft. If either of these concerns are noted, then a special evaluation should be conducted to demonstrate low stress and small deflections.

FOV/*R*S Caveat *8* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the valve.

8.2.1.2 GERS *Caveats* - Air-Operated Valves

The seismic capacity for the equipment class of air-operated valves *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class consists of spring-opposed, diaphragm-type pneumatic actuators which are designed to operate both gate and globe valves. They range in size from 12 to 40 inches in height (pipe centerline is reference position) with weights up to 500 pounds. The valves within this class are for 3-inch and smaller pipe sizes with design pressures less than 2,500 psi. A pneumatic actuator generally consists of a reinforced rubber diaphragm enclosed in a steel housing. The valve stem and diaphragm are attached so that any diaphragm movement results in valve movement. A solenoid valve controls the admission of high pressure air (100 to 150 psi) to the diaphragm housing. A return spring supplies sufficient counter force to close or open the valve when air pressure is not pushing on the diaphragm. The yoke of this class of pneumatic actuator is an integral part of the unit which is directly bolted to the valve bonnet. The valve body, bonnet, and yoke material should be carbon steel. The active components of the actuator are the solenoid valve, limit switches, and a pressure regulator, all of which are yoke-mounted appurtenances. This equipment class covers virtually all air-operated diaphragm valves used in small bore piping systems.

The GERS *(see Figure 8.2.1-4)* represent the seismic capacity of an Air-Operated Valve (AOV) if the valve meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

AOV/GERS Caveat 1 - Generic Seismic Testing Equipment Class. The valve should be similar to and bounded by the AOV class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

AOV/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The valve should meet all the caveats given for the *Reference* Spectrum. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

AOV/GERS Caveat 3 - Only Diaphragm-Type Air Operated Valves. The air-operated gate or globe valve should have a spring-opposed, diaphragm-type pneumatic actuator. This equipment class does not include piston-operated, pressure relief valves, or other diaphragm-type valves powered by fluids other than air. These valve types are the only types included in the generic seismic testing equipment class.

AOV/GERS Caveat 4 - Evaluation of Amplified Response. The valves and operators were tested with the valve fixed to the shake table. Therefore realistic amplification through the piping system should be included when determining the amplified response of the valve-to-pipe interface for comparison to the GERS.

AOV/GERS Caveat 5 - No Impact Allowed. A separate evaluation should be done to assure that the valve and operator will not impact surrounding structures and components as a result of pipe flexibility. The concern is that impact may damage the valve, operator, yoke, stem, or attached components. This type of damage has occurred in past earthquakes and is also identified as a seismic interaction concern.

AOV/GERS Caveat 6 - Nominal Pipe Size 1 to 3 Inches. The nominal pipe size of the valve should be within the range of 1 to 3 inches. This is the pipe size range included in the generic seismic testing equipment class.

AOV/GERS Caveat 7 - Carbon Steel Valve Body, Bonnet and Yoke. The valve body, bonnet, and yoke should all be carbon steel. Cast iron components are not covered by the GERS. It is not necessary to determine the material used for the valve body, bonnet, or yoke unless it appears to the *SCEs* that cast iron may have been used.

Figure 8.2.1-1 Air-Operated Valve from the Earthquake Experience Database

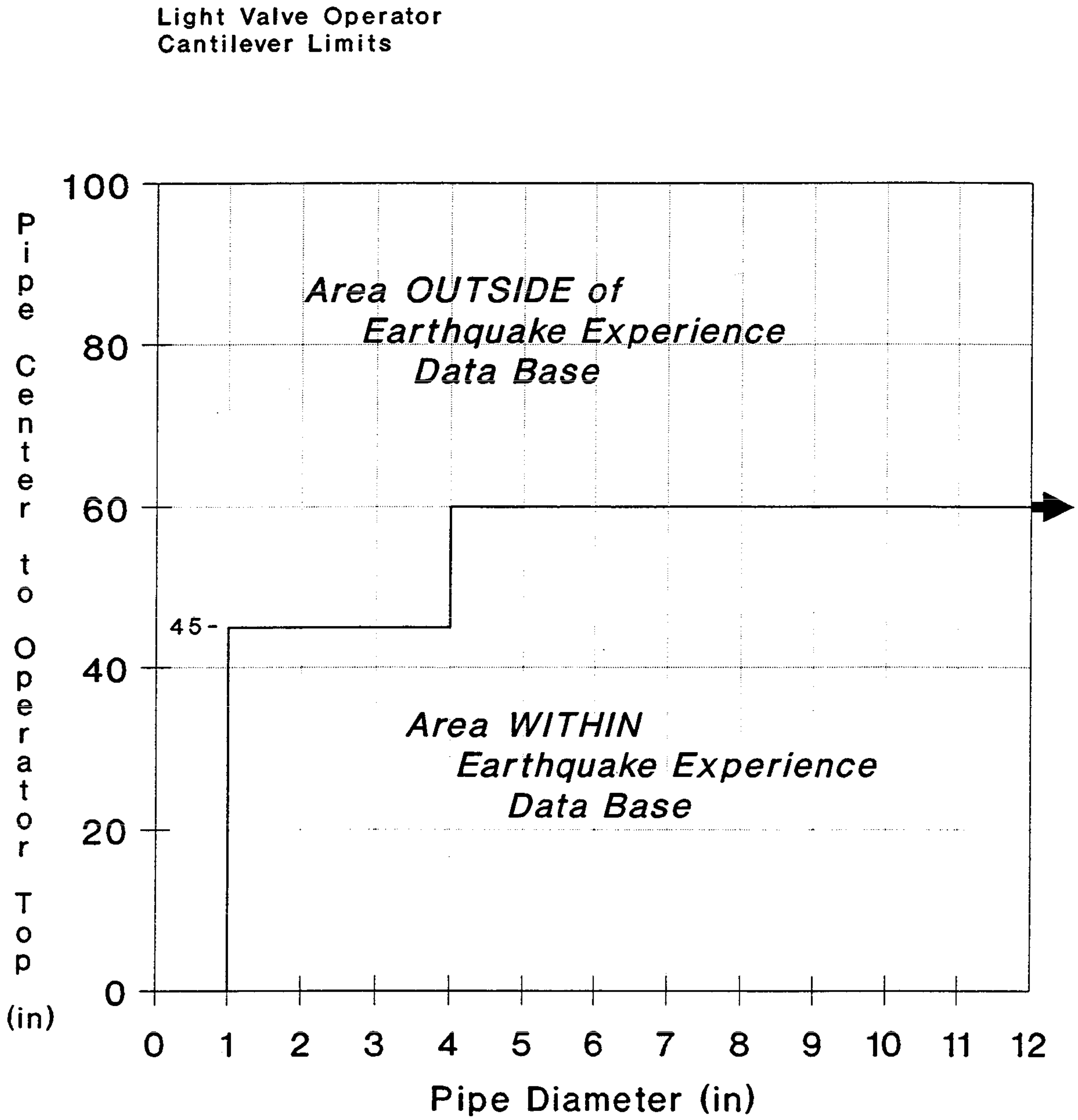


Figure 8.2.1-2 **Valve Operator Cantilever Length Limits for Air-Operated Diaphragm Valves, Spring-Operated Pressure Relief Valves, and Piston-Operated Valves of Light-Weight Construction (Reference 19) (Figure B.7-1 of SQUG GIP, Reference 1)**

Fluid-Operated Valves

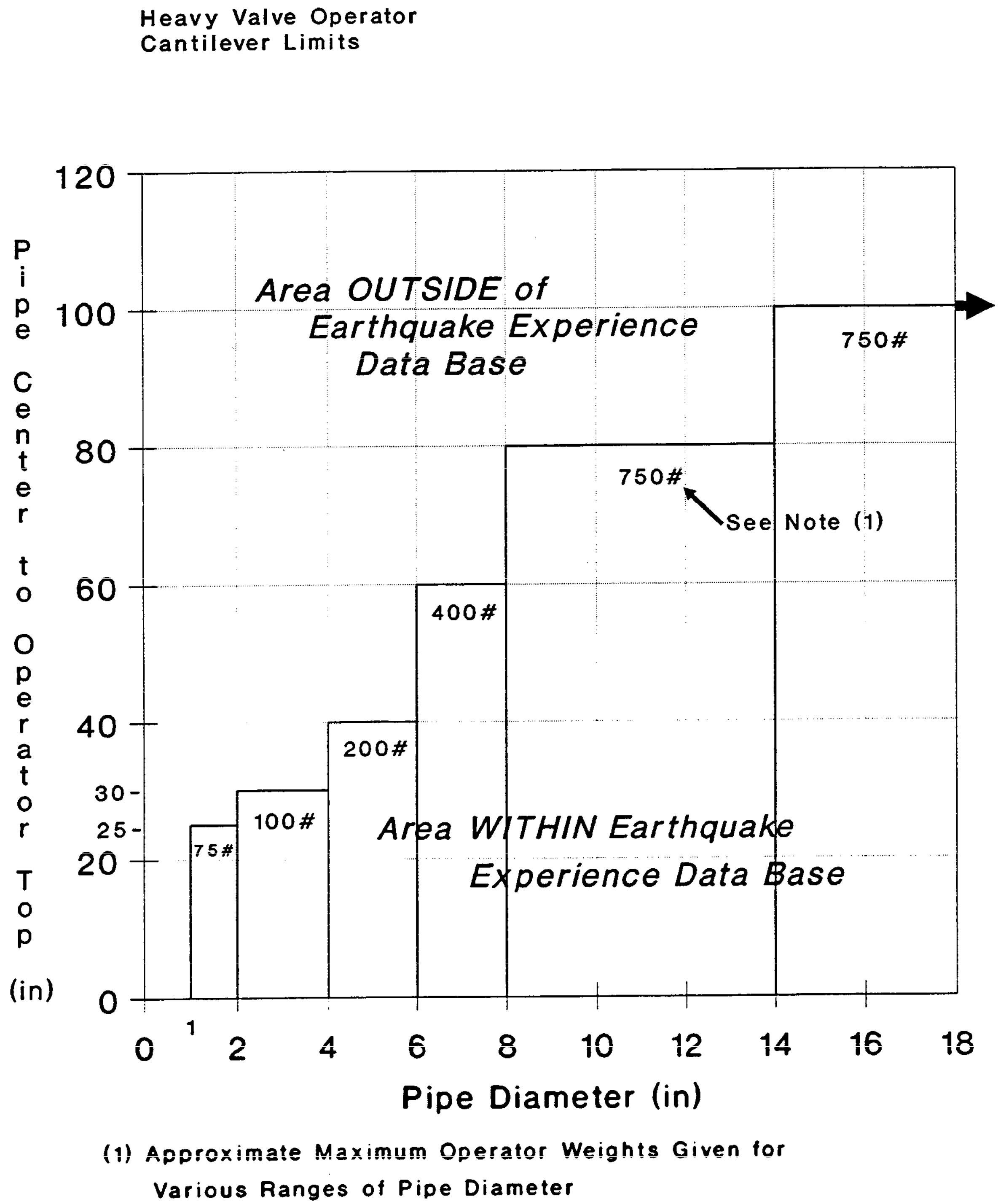
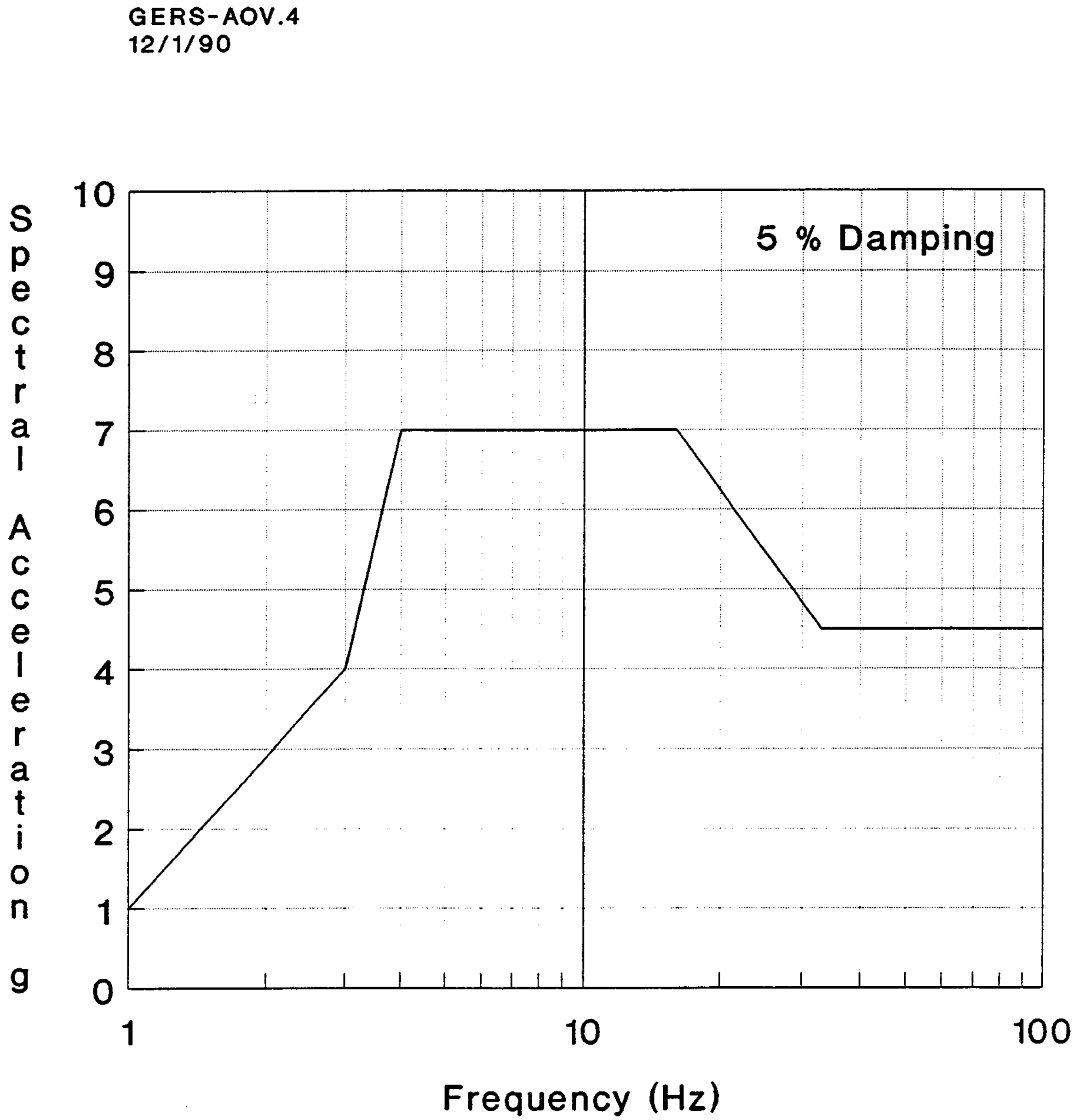


Figure 8.2.1-3 **Valve Operator Cantilever Length Limits for Piston-Operated Valves of Substantial Weight and Construction (Reference 19) (Figure B.7-2 of SQUG GIP, Reference 1)**



Frequency (Hz)	1	3	4	16	33
Air-Operated Valves (g)	1.0	4.0	7.0	7.0	4.5

Figure 8.2.1-4 Generic Equipment Ruggedness Spectra (GERS) for Air-Operated Valves (Reference 40) (Figure B.7-3 of SQUG GIP, Reference 1)

8.2.2 MOTOR-OPERATED / SOLENOID-OPERATED VALVES[2]

The seismic capacity for the equipment class of Motor-Operated Valves (MOV) *(see Figure 8.2.2-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes a wide diversity of sizes, types, and applications.

Components of a motor-operated valve include a motor operator with a control box, gear box, and drive motor. The gear box includes the gears which link the valve actuation to the drive motor shaft. Local controls typically include a relay for actuating the primary circuit to the motor, and torque and limit switches for coordinating the drive motor and the valve position. Valve operators may have a local motor controller built into the operator housing. The valve actuator shaft typically passes through the steel support frame or yoke. The valve which is actuated by a motor operator may be of any type, size, or orientation.

Motor operators may be mounted in any position (e.g., cantilevered vertically above, below, or to the side of the valve). The yoke, which connects the operator to the valve body, may take the form of a steel pipe enclosing the actuator shaft or a frame of welded beams. The attachments of the motor-gearbox to the yoke and the yoke to the valve are typically bolted flange connections, threaded connections, or ring clamps. In some applications, motor operators are mounted at a remote location above the valve.

The equipment class of motor-operated valves includes all valves actuated by an electric motor. The valve, the operator, *and the inlet and outlet lines and* attached conduit *up to their first support on the building or nearby structure* are included in the Motor-Operated Valve equipment class.

The seismic capacity for the equipment class of Solenoid-Operated Valves (SOV) (see Figure 8.2.2-2) may be based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes a wide diversity of sizes, types, and applications.

Solenoid operators are smaller and lighter than motor operators. Solenoid-operated valves are actuated by passing an electrical current through a coil, thereby creating a magnetic field which opens or closes the valve. Solenoid operators are generally more compact than motor operators with less of a cantilevered mass supported from the valve body. In addition, solenoid-operated valves are typically mounted on smaller diameter lines than MOVs.

The equipment class of solenoid-operated valves includes all valves actuated by a solenoid. The valve, the operator, and the inlet and outlet lines and attached conduit up to their first support on the building or nearby structure are included in the Solenoid-Operated Valve equipment class.

8.2.2.1 *Reference Spectrum Caveats - Motor-Operated Valves*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Motor-Operated Valve (MOV) if the valve meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

MOV/*R*S Caveat 1 - Earthquake Experience Equipment Class. The valve should be similar to and bounded by the MOV class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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[2] Section B.8 of SQUG GIP (Ref. 1)

MOV/*RS* Caveat 2 - Valve Body Not of Cast Iron. The valve body should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. It is not necessary to determine the material of the valve body unless it appears to the *SCEs* to be made of cast iron. It is suggested that the material of flanged valves be checked. In such cases, if the valve is indeed cast iron, the intent of this caveat is satisfied if seismic stresses in the valve body due to piping loads are low (for example, less than 20% of specified minimum ultimate tensile strength).

MOV/*RS* Caveat 3 - Valve Yoke Not of Cast Iron. The yoke of the motor-operated valve should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. It is not necessary to determine the material of the valve yoke unless it appears to be cast iron to the *SCEs*. In such cases, if the yoke is indeed cast iron, this caveat may be satisfied by performing a stress analysis of the valve for a 3g load applied at the center of gravity of the operator in the yoke's weakest direction. If the yoke stress is low (for example, less than 20% of specified minimum ultimate strength), then the intent of the caveat is satisfied.

MOV/*RS* Caveat 4 - Mounted on 1-Inch Diameter Pipe Line or Greater. The valve should be mounted on a pipe line of at least 1-inch diameter. This is the lower bound pipe size supporting MOVs in the earthquake experience equipment class. The concern is that valves with heavy operators on small lines may cause an overstressed condition in the adjacent piping. To satisfy the intent of this caveat a stress analysis (that accounts for the valve operator eccentricity) may be used to show that the pipe stress adjacent to the valve is low. There is no concern if the valve, the operator, and the line (if smaller than 1 inch) are well supported and anchored to the same support structure. This caveat does not apply to SOVs, which typically are installed on air lines smaller than 1 inch.

MOV/*RS* Caveat 5 - Valve Operator Cantilever Length for Motor-Operated Valves. The distance from the centerline of the pipe to the top of the operator or cylinder and the weight of the operator should not exceed the values given in Figure *8.2.2-3* corresponding to the diameter of the pipe. This bounds the earthquake experience equipment class. The concern is that longer operator lengths may lead to excessive valve yoke stress.

To meet the intent of this caveat the operator length or weight may be extrapolated by as much as 30% beyond that given in Figure 8.2.2-3 provided the product of the weight times the lever arm does not exceed the limits of Figure 8.2.2-3. If the ground motion spectra for the site is below the Reference Spectrum, over the entire frequency range possible for the piping and valve network, the operator weight or distance to the top of the operator can be increased by the ratio of the spectra. The cantilever length or the operator weight should not be increased by more than about 30% beyond the limits of Figure 8.2.2-3.

As an option, this caveat may also be satisfied by performing a stress analysis consisting of applying a 3g load at the center of gravity of the operator in the yoke's weakest direction. If the yoke stresses are low and the relative deflections are small (to ensure that shaft binding will not occur) then the caveat may be shown to be satisfied.

Alternatively, an in-situ static test may be conducted to demonstrate seismic adequacy. In these tests, a static force equal to three times the operator weight should be applied approximately at the center of gravity of the operator, non-concurrently in each of the three orthogonal principal axes of the yoke. Such tests should include demonstration of operability, i.e., the valve can open and close, following the application of the static loads. Note that all of the other limitations still apply.

A mockup test stand may be used provided that the details are similar to those in the *facility*. If there are numerous valves, a rational test program may be developed to envelop the valve configurations in the *facility*.

MOV/*RS* Caveat 6 - Actuator and Yoke Not Independently Braced. The valve actuator and yoke should not be independently braced to the structure or supported by the structure unless the pipe is also braced to the same structure immediately adjacent to the valve. The concern is that if the operator is independently supported from the valve and attached piping, then the operator may act as a pipe support during seismic motion and attract considerable load through the yoke and possibly fail the yoke or bind the shaft. In addition, if both the operator and the valve/pipe are restrained, and if they are both not tied back to the same structure, then differential motion of support points may lead to high seismic loads and possible binding of the shaft. If either of these concerns are noted, then a special evaluation should be conducted to demonstrate low stress and small deflections.

MOV/*RS* Caveat 7 - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the valve.

8.2.2.2 *Reference Spectrum Caveats - Solenoid-Operated Valves*

The Reference Spectrum (RS) represents the seismic capacity of a Solenoid-Operated Valve (SOV) if the valve meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

SOV/RS Caveat 1 - Earthquake Experience Equipment Class. The valve should be similar to and bounded by the SOV class of equipment described above. The equipment class descriptions are general and the SCEs should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

SOV/RS Caveat 2 - Valve Body Not of Cast Iron. The valve body should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. It is not necessary to determine the material of the valve body unless it appears to the SCEs to be made of cast iron. It is suggested that the material of flanged valves be checked. In such cases, if the valve is indeed cast iron, the intent of this caveat is satisfied if seismic stresses in the valve body due to piping loads are low (for example, less than 20% of specified minimum ultimate tensile strength).

SOV/RS Caveat 3 - Valve Yoke Not of Cast Iron. The yoke of the motor-operated valve should not be made of cast iron. The intent of this caveat is to avoid the brittle failure mode of cast iron as evidenced by the poor performance of some cast iron components in past earthquakes. It is not necessary to determine the material of the valve yoke unless it appears to be cast iron to the SCEs. In such cases, if the yoke is indeed cast iron, this caveat may be satisfied by performing a stress analysis of the valve for a 3g load applied at the center of gravity of the operator in the yoke's weakest direction. If the yoke stress is low (for example, less than 20% of specified minimum ultimate strength), then the intent of the caveat is satisfied.

SOV/RS Caveat 4 - Valve Operator Cantilever Length. The distance from the centerline of the pipe to the top of the operator or cylinder and the weight of the operator should not exceed the values given in Figure 8.2.2-3 corresponding to the diameter of the pipe. This bounds the earthquake experience equipment class. The concern is that longer operator lengths may lead to excessive valve yoke stress.

To meet the intent of this caveat the operator length or weight may be extrapolated by as much as 30% beyond that given in Figure 8.2.2-3 provided the product of the weight times the lever arm does not exceed the limits of Figure 8.2.2-3.

If the ground motion spectra for the site is below the Reference Spectrum, over the entire frequency range possible for the piping and valve network, the operator weight or distance to the top of the operator can be increased by the ratio of the spectra. The cantilever length or the operator weight should not be increased by more than about 30% beyond the limits of Figure 8.2.2-3.

As an option, this caveat may also be satisfied by performing a stress analysis consisting of applying a 3g load at the center of gravity of the operator in the yoke's weakest direction. If the yoke stresses are low and the relative deflections are small (to ensure that shaft binding will not occur) then the caveat may be shown to be satisfied.

Alternatively, an in-situ static test may be conducted to demonstrate seismic adequacy. In these tests, a static force equal to three times the operator weight should be applied approximately at the center of gravity of the operator, non-concurrently in each of the three orthogonal principal axes of the yoke. Such tests should include demonstration of operability, i.e., the valve can open and close, following the application of the static loads. Note that all of the other limitations still apply.

A mockup test stand may be used provided that the details are similar to those in the facility. If there are numerous valves, a rational test program may be developed to envelop the valve configurations in the facility.

<u>SOV/RS Caveat 5 - Actuator and Yoke Not Independently Braced.</u> The valve actuator and yoke should not be independently braced to the structure or supported by the structure unless the pipe is also braced to the same structure immediately adjacent to the valve. The concern is that if the operator is independently supported from the valve and attached piping, then the operator may act as a pipe support during seismic motion and attract considerable load through the yoke and possibly fail the yoke or bind the shaft. In addition, if both the operator and the valve/pipe are restrained, and if they are both not tied back to the same structure, then differential motion of support points may lead to high seismic loads and possible binding of the shaft. If either of these concerns are noted, then a special evaluation should be conducted to demonstrate low stress and small deflections.

<u>SOV/RS Caveat 6 - Any Other Concerns?</u> SCEs should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the valve.

8.2.2.3 <u>GERS *Caveats* - Motor-*Operated* Valves</u>

The seismic capacity for the equipment class of electric motor operators for valves (MOV) *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class includes operators designed to control the five major types of valves (gate, globe, plug, ball, and butterfly). They range in weight from 150 pounds up to 3,500 pounds. A valve operator consists of a metal housing which connects to the valve body by a flange or yoke and contains limit switches, a torque switch, an electric motor, a clutch, gears, and bearings. For this class of equipment, the motor controls (reversing starter, overload relays, and push-button station) should be located in a remote location (usually a motor control center). For some valve configurations, the valve actuators are mounted on secondary reducers resulting in the actuator being eccentric and cantilevered from the valve body. For these configurations, a special seismic bracket supplied by the manufacturer is required. The mounting position of the valve operator is with the motor horizontal and the limit switch compartment horizontal or vertical as specified by the manufacturer. These positions will insure the proper distribution of lubricants through the internal working component of the units. This equipment class covers virtually all motor-driven valve operators used in *facilities*.

The MOV GERS *(see Figure 8.2.2-4)* represent the seismic capacity of an electric Motor Operator for a Valve (MOV) if the operator meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

<u>MOV/GERS Caveat 1 - Generic Seismic Testing Equipment Class.</u> The electric motor-driven valve operator should be similar to and bounded by the MOV class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

<u>MOV/GERS Caveat 2 - *Reference* Spectrum Caveats Apply.</u> The operator should meet all the caveats given for the *Reference* Spectrum for the MOV class of equipment. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

<u>MOV/GERS Caveat 3 - Evaluation of Amplified Response.</u> The GERS were based on tests in which the operators were mounted directly to the shake table and not on a valve yoke structure or a valve. Therefore realistic amplification through the piping system and valve should be included when determining the seismic demand at the operator-to-valve interface for comparison to the GERS. Note also that the MOV GERS apply only to the operator; the seismic adequacy of the valve and its yoke should be evaluated separately.

<u>MOV/GERS Caveat 4 - Motor Axis Horizontal.</u> The motor axis should be horizontal and the limit switch compartment should be horizontal or vertical (definition of orientation directions provided in manufacturer's submittals). These were the positions of the motor axis and limit switch compartment in the generic seismic testing equipment class shake table tests.

<u>MOV/GERS Caveat 5 - No Impact Allowed</u>. A separate evaluation should be done to assure that the operator will not impact surrounding structures and components as a result of pipe flexibility. The concern is that impact may damage the operator, yoke, stem, or attached components. This type of damage has occurred in past earthquakes and is also identified as a seismic interaction concern.

<u>MOV/GERS Caveat 6 - Motor Controls Remotely Located.</u> The motor controls (reversing starter, overload relays, and push-button station) should be remotely located and separately evaluated. The motor controls were not located on the valve operators during the GERS testing and are therefore not included in the generic seismic testing equipment class.

<u>MOV/GERS Caveat 7 - Seismic Brackets for Side-Mounted Actuators.</u> Side-mounted valve actuators attached to secondary reducers should have seismic brackets as supplied by the manufacturer (review of manufacturer's submittals is sufficient). The actuators in the GERS tests that were tested in this orientation had seismic brackets.

<u>MOV/GERS Caveat 8 - Manufactured by Limitorque or Rotork.</u> The operator should be manufactured by either Limitorque or Rotork. These are the MOV manufacturers included in the generic seismic testing equipment class.

MOV/GERS Caveat 9 - Tighten Loose Valve-to-Operator Bolts. Any missing or loose valve-to-operator bolts which are noticed during the walkdown should be replaced or retightened; a tightness check is not required.

8.2.2.4 GERS *Caveats* - Solenoid-Operated Valves

The seismic capacity for the equipment class of solenoid-operated valves (SOV) *may be* based on generic testing data, provided the intent of each of the caveats listed below is met. This equipment class consists of a combination of two basic functional units: 1) a solenoid actuator (electro-magnet) with its plunger (or core), and 2) a valve body containing an orifice in which a disc or plug is positioned to stop or allow flow. The valve is opened or closed by movement of the magnetic plunger which is drawn into the solenoid when the coil is energized. Solenoid valves can be either two-way, three-way or four-way valves. In the direct acting two-way solenoid valve, the solenoid acts directly on the valve stem to open or close the valve. Three-way solenoid valves are principally used as pilot valves to alternately apply pressure to and exhaust pressure from a diaphragm valve actuator. Four-way solenoid valves are often used for controlling double-acting pneumatic or hydraulic cylinders. The valves range in weight from a few pounds to 45 pounds and are made of either forged brass or steel. The valves within this class are for pipe sizes which are 1 inch or less in diameter and for design pressures less than 600 psi. This equipment class covers virtually all solenoid-operated valves used in small bore piping or process air systems.

The SOV GERS *(see Figure 8.2.2-5)* represent the seismic capacity of a Solenoid-Operated Valve if the valve meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

SOV/GERS Caveat 1 - Generic Seismic Testing Equipment Class. The valve should be similar to and bounded by the SOV class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

SOV/GERS Caveat 2 - *Reference* Spectrum Caveats Apply. The valve should meet all the caveats given for the *Reference* Spectrum for the class of equipment. This caveat is included to cover the vulnerabilities identified for the earthquake experience equipment class. Those GERS caveats which are the same as the *Reference* Spectrum caveats are not repeated below.

SOV/GERS Caveat 3 - Evaluation of Amplified Response. The valves and operators were tested with the valve fixed to the shake table. Therefore realistic amplification through the piping system should be included when determining the amplified response of the valve-to-pipe interface for comparison to the GERS.

SOV/GERS Caveat 4 - No Impact Allowed. A separate evaluation should be done to assure that the valve and operator will not impact surrounding structures and components as a result of pipe flexibility. The concern is that impact may damage the valve, operator, yoke, stem, or attached components. This type of damage has occurred in past earthquakes and is also identified as a seismic interaction action concern.

SOV/GERS Caveat 5 - Nominal Pipe Size 1 Inch or Less. The nominal pipe size of the valve should be 1 inch or less. This is the upper bound pipe size included in the generic seismic testing equipment class.

SOV/GERS Caveat 6 - Forged Brass or Steel Valve Body. The valve body should be made of either forged brass or steel. Other materials are not covered by the generic seismic testing equipment class.

SOV/GERS Caveat 7 - Orientation of Solenoid Housing. The solenoid housing should be oriented in accordance with the manufacturer's recommendations for the specific model (review of manufacturer's submittals is sufficient). GERS testing was performed with the solenoid housing in the recommended orientation.

SOV/GERS Caveat 8 - Overall Height Not to Exceed 12 Inches. The overall height of the valve (pipe centerline to top of solenoid housing) should not exceed 12 inches. This is the upper bound height limit included in the generic seismic testing equipment class.

SOV/GERS Caveat 9 - Separate Evaluation of Main Valve Controlled By SOV. When the Solenoid-Operated Valve is a pilot valve in a valve assembly, the main valve should be evaluated separately. Note that the amplified response spectra at the attachment point of the SOV should be used in the SOV evaluation as discussed in SOV/GERS Caveat 3.

SOV/GERS Caveat 10 - Lower ZPA for ASCO Type 206-381. For ASCO Type 206-381 solenoid valves, the GERS with a 3.5g ZPA should be used.

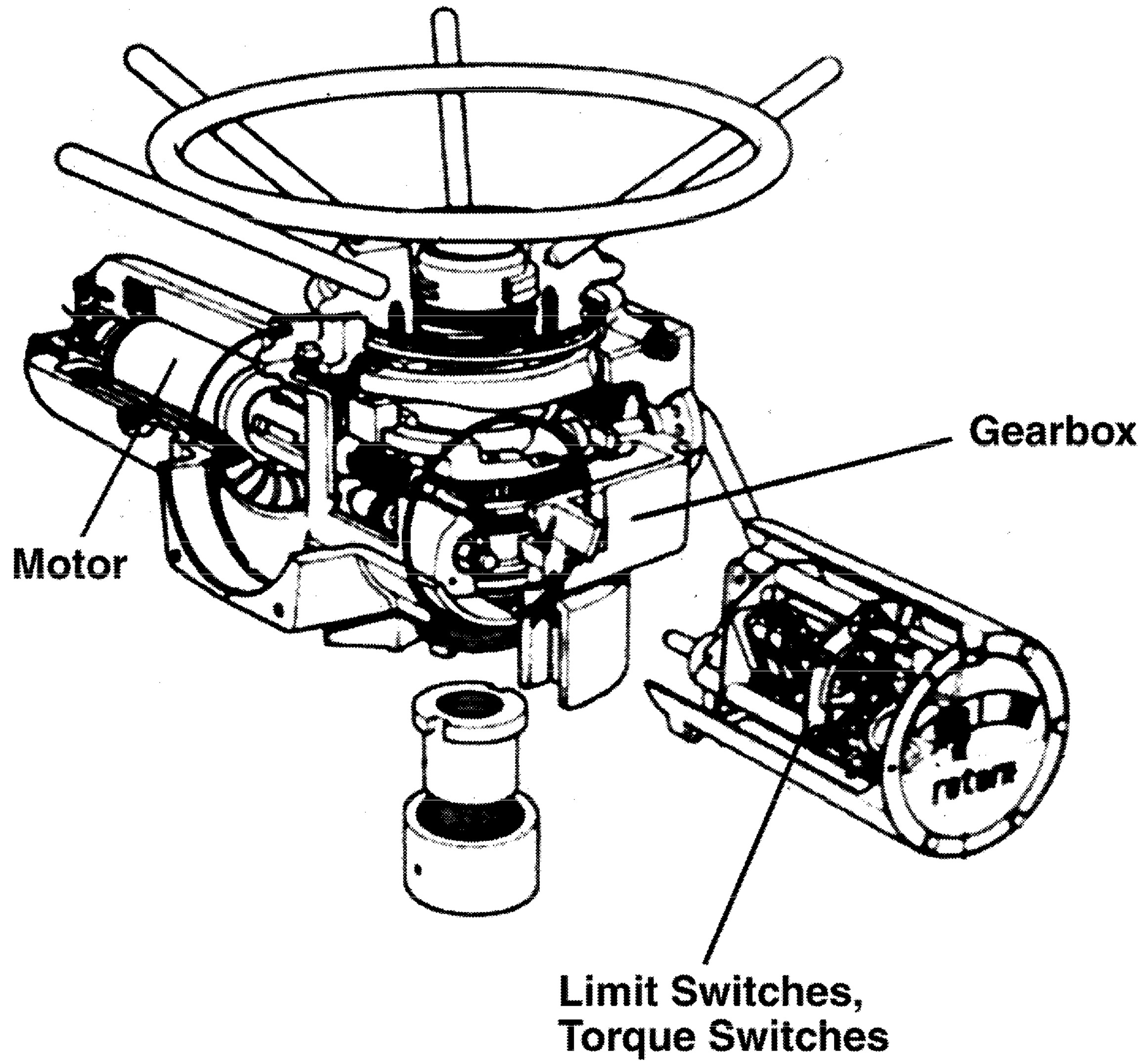


Figure 8.2.2-1 Motor-Operated Valve

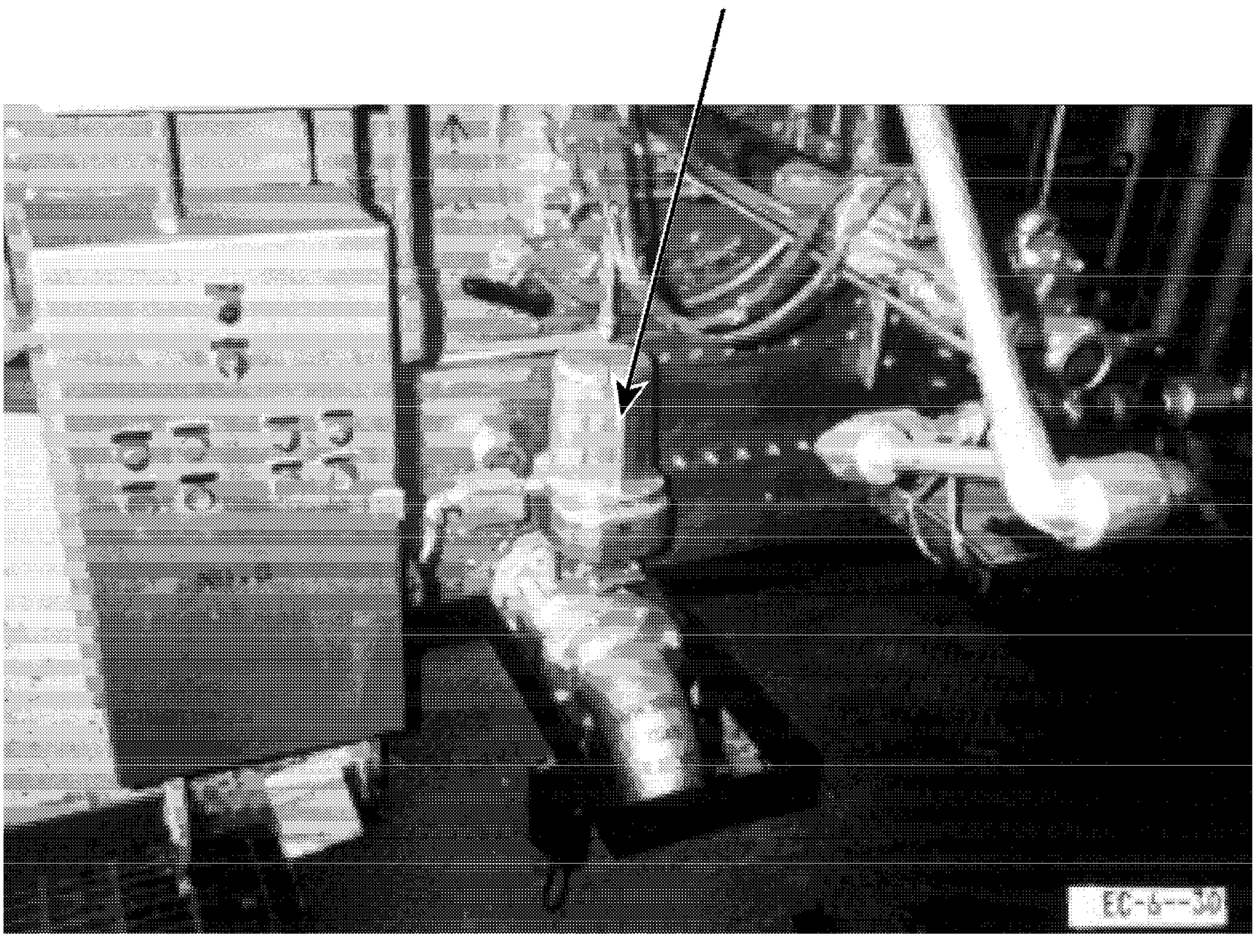
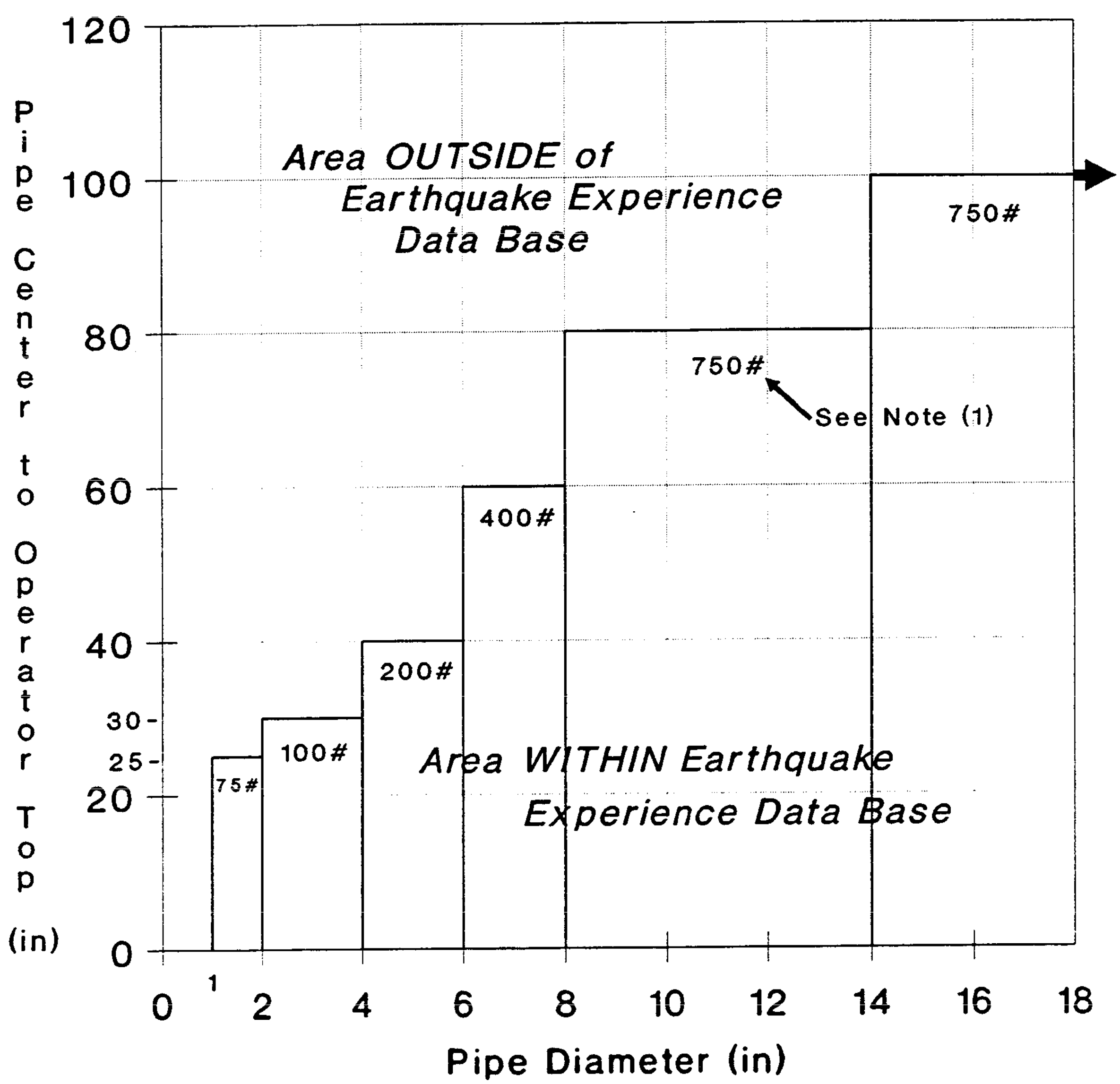


Figure 8.2.2-2 Solenoid-Operated Valve from the Earthquake Experience Database

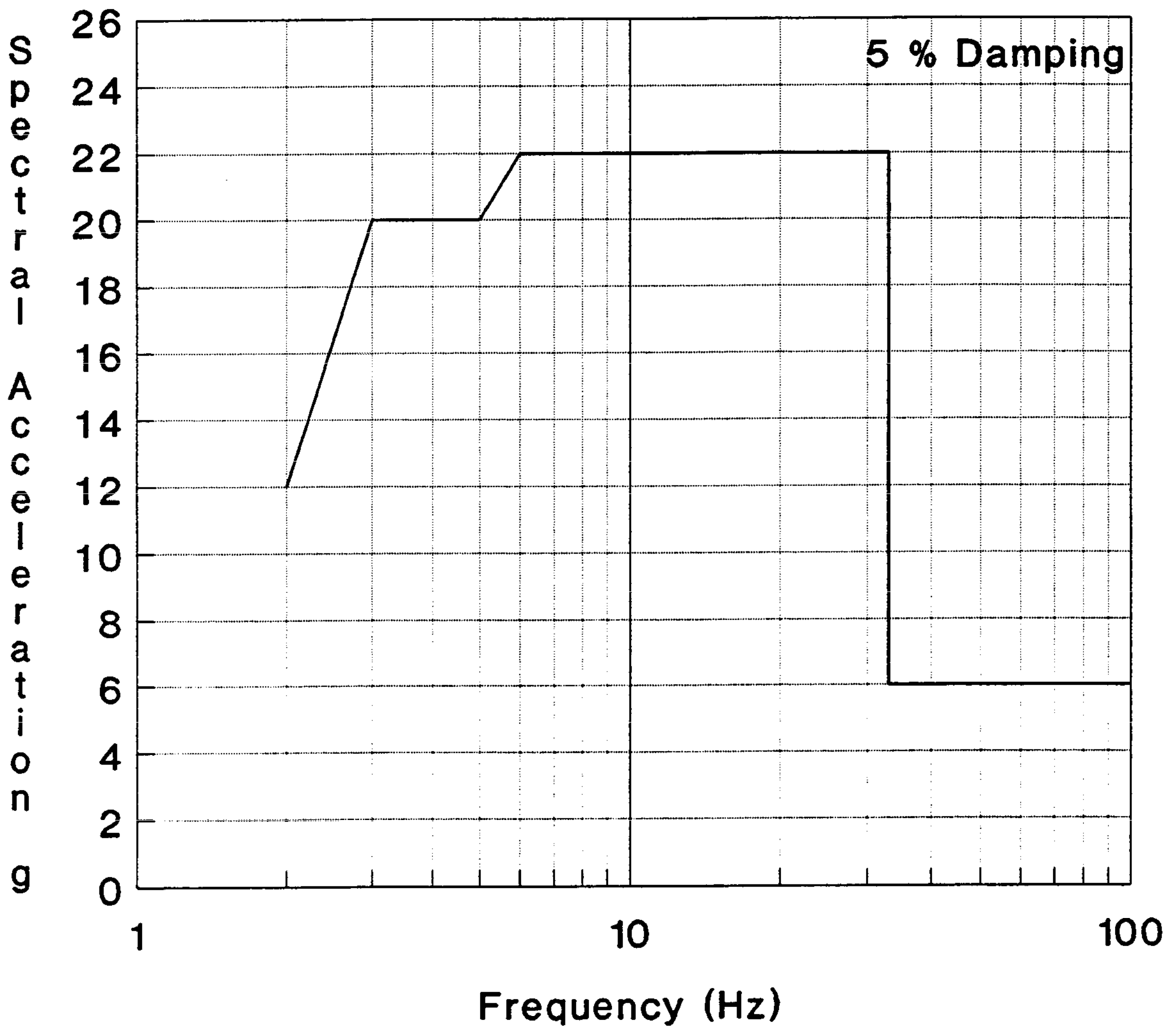
Motor-Operated and Solenoid-
Operated Valves

Heavy Valve Operator
Cantilever Limits



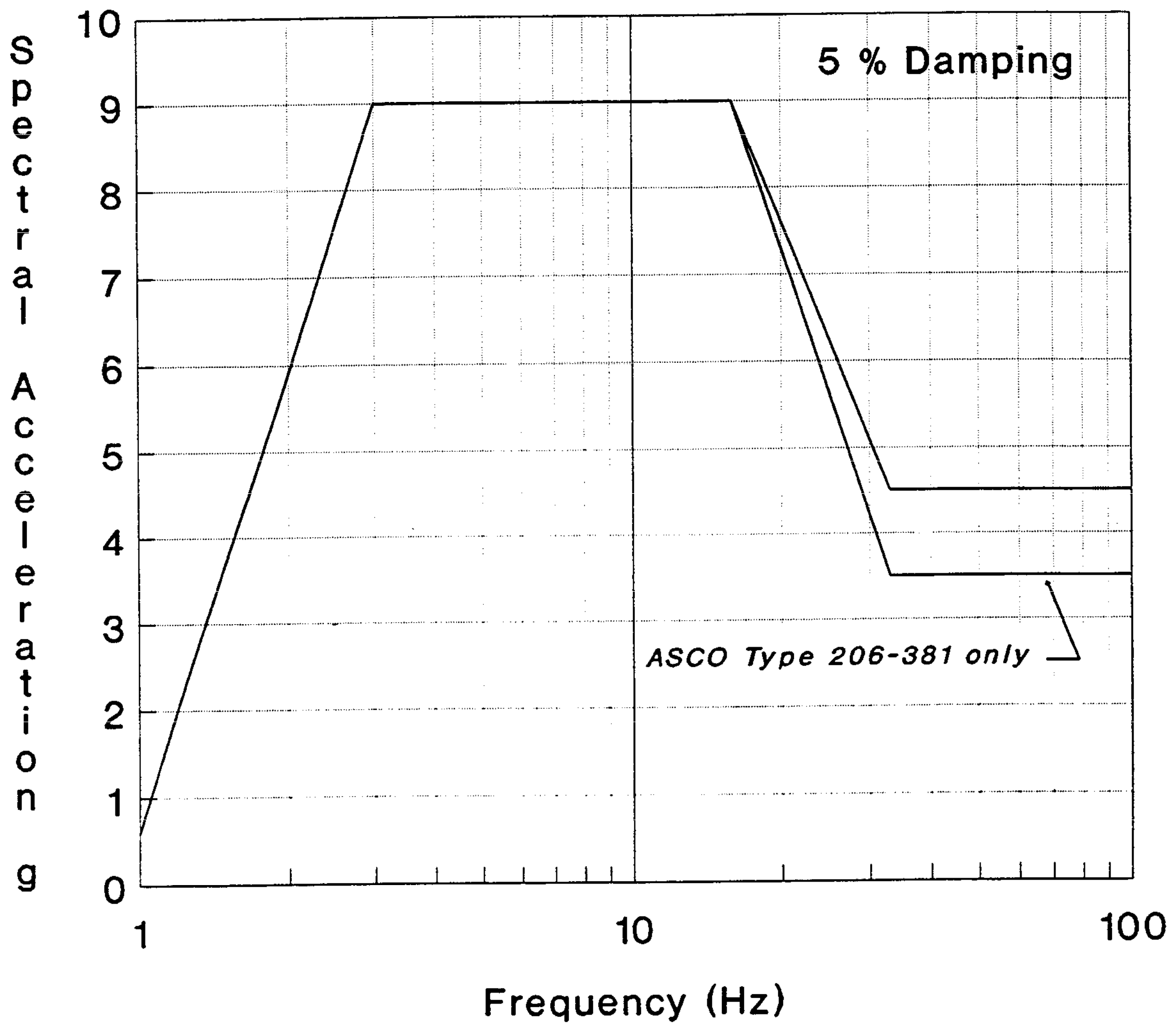
(1) Approximate Maximum Operator Weights Given for Various Ranges of Pipe Diameter

Figure 8.2.2-3 Valve Operator Cantilever Length Limits for Motor-Operated Valves (Figure B.8-1 of SQUG GIP, Reference 1)



Frequency (Hz)	2	3	5	6	33	33
Motor Operators for Valves (g)	12	20	20	22	22	6

Figure 8.2.2-4 **Generic Equipment Ruggedness Spectra (GERS) for Motor Operators On Valves (Reference 40) (Figure B.8-2 of SQUG GIP, Reference 1)**



Frequency (Hz)	1	3	16	33
Solenoid Valves - General (g)	0.6	9.0	9.0	4.5
ASCO Type 206-381 only (g)	0.6	9.0	9.0	3.5

Figure 8.2.2-5 Generic Equipment Ruggedness Spectra (GERS) for Solenoid-Operated Valves (Reference 40) (Figure B.8-3 of SQUG GIP, Reference 1)

8.2.3 HORIZONTAL PUMPS[3]

The seismic capacity for the equipment class of Horizontal Pumps (HP) *(see Figure 8.2.3-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes all pumps commonly found in applications which have their axes aligned horizontally. The class includes pumps driven by electric motors, reciprocating piston engines, and steam turbines. The common peripheral components such as conduit, instrumentation, and suction and discharge lines up to their first *support on the building or nearby structure* are included in this equipment class.

Pumps can generally be categorized as either kinetic (rotary impeller) or positive displacement types. Kinetic pumps move fluid using the kinetic energy of a rotating impeller. Positive displacement pumps move fluid by volumetric displacement.

Single-stage kinetic pumps typically include a single impeller that moves fluid primarily by centrifugal force. The suction port is normally mounted along or near the impeller axis, and the discharge port is mounted near the periphery. Pumps may range in size from fractional horsepower units, with capacities of a few gallons per minute (gpm), to units requiring several thousand horsepower, with capacities of tens of thousands of gpm.

Multi-stage kinetic pumps include two or more impellers working in series on a single shaft. Depending on the impeller design, multi-stage pumps move fluid using either centrifugal force toward the periphery of the impeller, or propeller force along the axis of the impeller. The impeller is surrounded by a stationary casing or volute that directs the flow from the discharge of one impeller to the intake of the next.

Kinetic pumps are usually powered by electric motors with the pump and motor sharing the same shaft through a close-coupled connection. Larger multi-stage pumps sometimes couple the motor and pump through a gearbox, which allows the pump and motor to turn at different speeds. Single-stage pumps are occasionally belt-driven, with the motor mounted to the side, or even atop the pump casing. Smaller, single-stage pumps sometimes mount the motor and impeller within the same casing. Larger pumps, both single- and multi-stage, normally have the motor and pump in separate casings, with both casings anchored to the same steel skid. Kinetic pumps may also be powered by engines or steam turbines.

Reciprocating-piston positive displacement pumps are similar in design to reciprocating-piston air compressors. They include an electric motor that powers a set of piston impellers through a shaft or belt connection. The piston impellers are usually mounted within a cast block that also contains the piston crank shaft and valve mechanism.

Rotary-screw positive displacement pumps are somewhat similar to multi-stage kinetic pumps, except that the screw impeller moves fluid axially through volume displacement rather than through a transfer of kinetic energy from the impeller to the fluid. The screw impeller is normally powered by an electric motor through a close-coupled shaft.

Kinetic and positive displacement horizontal pumps driven by electric motors, engines, and turbines are represented in the range from 5 to 2300 hp and 45 to 36,000 gpm. Submersible pumps are not included in this equipment class.

There are no GERS for Horizontal Pumps.

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[3] Section B.5 of SQUG GIP (Ref. 1)

8.2.3.1 *Reference Spectrum Caveats - Horizontal Pumps*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Horizontal Pump (HP) if the pump meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

HP/*R*S Caveat 1 - Earthquake Experience Equipment Class. The horizontal pump should be similar to and bounded by the HP class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

HP/*R*S Caveat 2 - Driver and Pump on Rigid Skid. The driver and pump should be connected by a rigid base or common skid. The concern is that differential displacement between the pump and driver may cause shaft misalignment. If they are not mounted on a rigid skid, the potential for differential displacement between the driver and pump should be specially evaluated.

HP/*R*S Caveat 3 - Thrust Bearings in Both Axial Directions. Thrust restraint of the shaft in both axial directions should exist. The concern arose from shake table testing on pumps without thrust bearings that performed poorly. In general, pumps from U.S. manufacturers have such axial thrust restraint so that explicit *determination* is not necessary; however, any indication to the contrary should be investigated.

HP/*R*S Caveat 4 - Check of Long Unsupported Piping. Brief consideration should be given to identify situations where the horizontal pump may be affected by gross pipe motion, differential displacement, and excessive nozzle loads. The concern is that excessive force on pump nozzles could potentially break the pump nozzle or cause sufficient pump case distortion to cause binding, or fail the anchorage. These excessive forces are uncommon and need only be considered if there is a long section of unsupported pipe or a heavy valve attached to the pipe near the pump.

HP/*R*S Caveat 5 - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the pump.

Figure 8.2.3-1 Horizontal Pump from the Earthquake Experience Database

8.2.4 VERTICAL PUMPS[4]

The seismic capacity for the equipment class of Vertical Pumps (VP) *(see Figure 8.2.4-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes pumps with the impeller drive shaft mounted in a vertical (as opposed to horizontal) direction. Vertical pumps are typically powered by an electric drive motor, vertically aligned, and mounted atop a steel or cast-iron support frame that is anchored to a concrete base pad.

The two general types of vertical pumps represented in the earthquake experience equipment class are deep-well pumps and centrifugal pumps. Motor sizes range from 5 to 7000 hp and flow rates range from 95 to 16,000 gpm.

Deep-well turbine type pumps have the pump impeller attached to the bottom of a long vertical drive shaft extending beneath the pump base plate. The pump drive shaft is enclosed in a steel or cast iron casing which extends below the pump base plate. The pump impeller is mounted in a contoured housing or bowl at the base of the casing. The casing or suction pipe is immersed in a well and opened at the bottom for fluid inlet.

A variation of the deep-well turbine pump is the can-type pump. The casing that encloses the impeller drive shaft is, in turn, enclosed by an outer casing or can. Fluid feed to the pump flows through an inlet line, usually mounted in the support frame above the pump base plate. The can forms an annular reservoir of fluid that is drawn into the impeller at the base of the inner casing.

Deep-well pumps range in size from fractional horsepower units to pumps of several thousand horsepower. The casings, cantilevered below the base plate, have typical lengths of 10 to 20 feet. The most massive component of the pump is normally the drive motor, which may weigh several tons.

Single-stage centrifugal pumps are configured with the impeller mounted above the base plate, directly beneath the drive motor. The impeller is housed in a casing that is usually part of the support frame for the drive motor. Instead of drawing fluid from a well or can beneath the pump base plate, the fluid inlet is a piping attachment aligned with a centerline of the impeller drive shaft. The discharge line is tangential to the periphery of the centrifugal impeller casing. Smaller centrifugal pumps are sometimes mounted directly on the piping system they serve.

The pump, drive motor, associated instrumentation and controls attached to the pump, and attached piping and conduit up *to their first support on the building or nearby structure* are included in the vertical pump equipment class. The equipment class does not include submersible pumps.

There are no GERS for Vertical Pumps.

8.2.4.1 Reference Spectrum Caveats - Vertical Pumps

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Vertical Pump (VP) if the pump meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

VP/*R*S Caveat 1 - Earthquake Experience Equipment Class. The vertical pump should be similar to and bounded by the VP class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may

[4] Section B.6 of SQUG GIP (Ref. 1)

not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

VP/*RS* Caveat 2 - Cantilever Impeller Shaft Less Than 20 Feet Long. The impeller shaft and casing should not be cantilevered more than 20 feet below the pump mounting flange. This type of cantilever vertical pump should have a radial bearing at the bottom of the casing to support the impeller shaft. Twenty (20) feet represents the upper bound length of cantilever shafts of vertical pumps in the earthquake experience equipment class. The concern is that pumps with longer lengths may be subject to misalignment and bearing damage due to excessive lateral loads, damage to the impeller due to excessive displacement, and damage due to interfloor displacement on multi-floor supported pumps. Either individual analysis or use of another method as a means of evaluating vertical pumps should be used when the shaft cantilever length exceeds 20 feet. The evaluation should address the concerns of excessive shaft and casing stresses and deflection of the impeller drive shaft.

VP/*RS* Caveat 3 - Check of Long Unsupported Piping. Brief consideration should be given to identify situations where the vertical pump may be affected by gross pipe motion, differential displacement, and excessive nozzle loads. The concern is that excessive force on pump nozzles could potentially break the pump nozzle or cause sufficient pump case distortion to cause binding, or fail the anchorage. These excessive forces are uncommon and need only be considered if there is a long section of unsupported pipe or a heavy valve attached to the pipe near the pump.

VP/*RS* Caveat *4* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the pump.

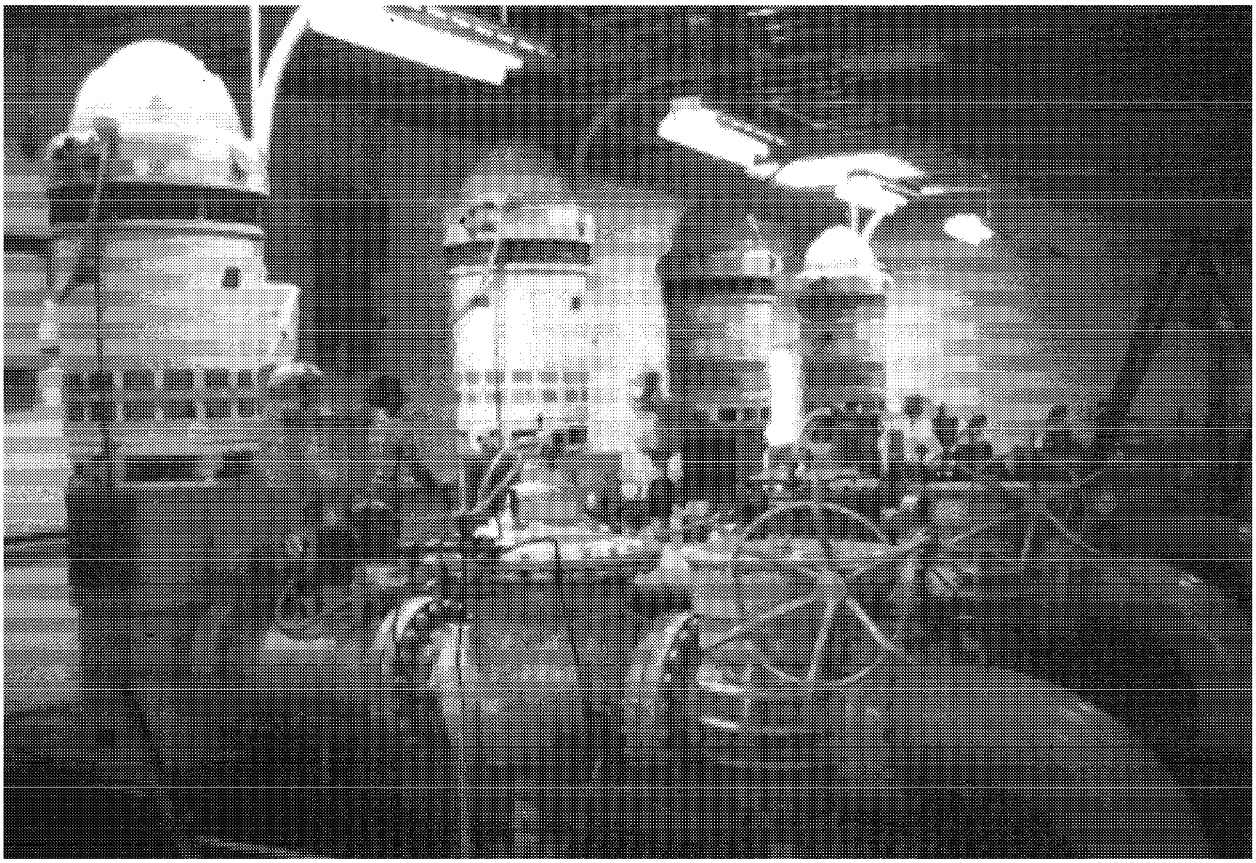

Figure 8.2.4-1 Vertical Pumps from the Earthquake Experience Database

8.2.5 CHILLERS[5]

The seismic capacity for the equipment class of Chillers (CHL) *(see Figure 8.2.5-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes skid-mounted units comprised of components such as a compressor, a condenser, an evaporator, and a control and instrumentation panel. Chillers condense refrigerant or chill water for indoor climate-control systems which supply conditioned air for equipment operating environments and for personnel comfort.

Compressors draw vaporized refrigerant from the evaporator and force it into the condenser. The compressor of a chiller unit may be either the centrifugal or the reciprocating piston type. Condensers are heat exchangers which reduce the refrigerant from a vapor to a liquid state. Chiller condensers are usually shell- and tube-type heat exchangers, with refrigerant on the shell side. Evaporators are tube bundles over which refrigerant is sprayed and evaporated, the inverse function of the condenser. Evaporator tubes can have either finned or plain surfaces. Control panels provide local chiller system monitoring and control functions. Typical components include: oil level switches/gauges, temperature switches/gauges, pressure switches/gauges, undervoltage and phase protection relays, and compressor motor circuit breakers.

Chiller components may be arranged in a variety of configurations. Typically the evaporator and condenser are mounted in a stacked configuration, one above the other, with the compressor and the control panel mounted on the side. Variations of this arrangement include the side-by-side configuration, with the compressor usually mounted above the condenser and evaporator, or a configuration with all components mounted side by side on the skid. Components are usually bolted to a supporting steel skid, which is, in turn, bolted to a concrete pad. Attachments to chillers include piping for routing cooling water or refrigerant to the unit, electrical conduit, and instrumentation and control lines. Chiller weights range up to about 40,000 lbs.

The compressor, condenser, evaporator, local control panel, support framing, and attached piping, instrument lines, and conduit which are attached to the same skid are included in the Chiller equipment class.

There are no GERS for Chiller Units.

8.2.5.1 *Reference Spectrum Caveats - Chillers*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Chiller (CHL) if the chiller meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

CHL/*R*S Caveat 1 - Earthquake Experience Equipment Class. The chiller should be similar to and bounded by the CHL class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

CHL/*R*S Caveat 2 - No Reliance on Weak-Way Bending of Steel Plate or Structural Steel Shapes. The evaporator and condenser tanks should be reasonably braced between themselves for lateral forces parallel to the axis of the tanks without relying on weak-way bending of steel plate or webs of structural steel shapes. The concern is that in weak-way bending the structure will not be capable of transferring the lateral earthquake loads. If weak-way steel plate bending must be relied

[5] Section B.11 of SQUG GIP (Ref. 1)

on to brace the upper tank, then the adequacy of the steel components should be specially evaluated for adequate strength and stiffness.

<u>CHL/*RS* Caveat *3* - Any Other Concerns?</u> *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the chiller.

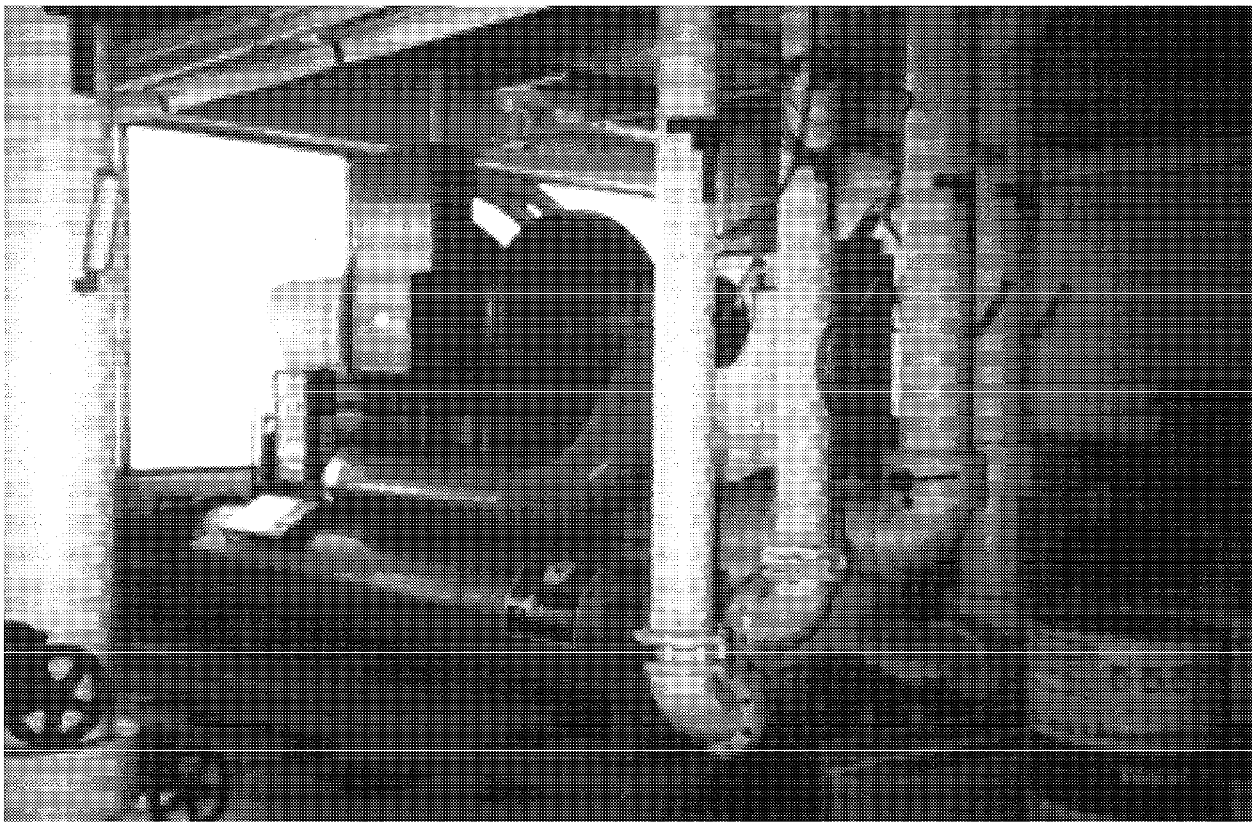

Figure 8.2.5-1 Chillers from the Earthquake Experience Database

8.2.6 AIR COMPRESSORS[6]

The seismic capacity for the equipment class of Air Compressor (AC) *(see Figure 8.2.6-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes freestanding air compressors together with attached components such as air intakes, air receiver tanks, local control panels, conduit, and discharge lines. Air compressors can be generally categorized as reciprocating piston or rotary screw. The equipment class of air compressors encompasses a wide range of sizes, configurations, and applications. Air compressors typically include as components: electric drive motor, piston- or impeller-driven compressor, air receiver tank, air intake filter, air aftercooler, moisture separator, lubrication system, and the control and instrument panel. Large compressors typically include water jackets to cool the compressor casing and the air aftercoolers, while smaller units are typically cooled by natural or fan-assisted convection to the surrounding air.

Air compressors supply operating pressure to pneumatic instrumentation and control systems, in particular to diaphragm-operated valves. Air compressors also charge pressurized air receiver tanks that serve the pneumatic starting systems for emergency engine-generators.

Compressor configurations in the equipment class include air receiver tank-mounted reciprocating piston or rotary screw compressors, skid-mounted reciprocating piston or rotary screw compressors, and freestanding reciprocating piston compressors.

Reciprocating piston compressors are constructed much like an automobile engine, with pistons encased in cast steel cylinders compressing the gas, and a system of timed valves controlling the inlet and discharge. Drive motor sizes typically range from fractional horsepower to over 100 horsepower. Piston air compressors generally have one or two cylinders but may include more. Cylinders are normally supported on a cast iron crankcase, which encloses the rotating crankshaft, linked either directly to the electric motor through a drive shaft, or indirectly through a belt linkage. Smaller reciprocating piston compressors are commonly mounted atop an air receiver tank.

Rotary screw compressors replace the reciprocating piston with a set of helical screws, typically encased in a cast iron block. The components and attachments of the air compressor are similar to reciprocating piston units except that the system of timed intake and discharge valves are not required. The most common configuration has the air compressor mounted on top of its air receiver tank. The units are usually not large, ranging in capacity from about 1 to 100 cfm (cubic feet per minute of discharge air), with drive motors typically ranging from fractional horsepower up to 30 hp. Tank-mounted rotary screw compressors typically range in weight from about 200 to 2500 pounds.

Reciprocating piston and rotary screw compressors may also be mounted on a steel skid. The skid may be either open or enclosed in a sheet metal housing. The skid is normally constructed of a welded steel frame with the compressor, drive motor, receiver tank, control panel, and other components bolted to the frame in some convenient configuration. Skid-mounted compressors typically range in capacity up to about 2000 cfm, with drive motors of up to about 300 hp. Skid-mounted compressors typically range in weight from about 2000 to 8000 pounds.

Freestanding compressors are usually the reciprocating piston type with one or two cylinders normally cantilevered from a crankcase. The crankcase may form the primary support for all components, or it may be mounted on a steel or cast iron pedestal. Freestanding compressors include the largest units typically found in *facility* applications, ranging in capacity up to about 4000 cfm, with drive motors up to about 1000 hp. Freestanding compressors range in weight from small units on the order of about 500 pounds to units as large as 10 tons.

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6 Section B.12 of SQUG GIP (Ref. 1)

The Air Compressor equipment class includes the piston- or impeller-driven compressor, drive motor, air receiver tank, and attached cooling coils and air intakes, attached air discharge lines, instrument lines, and attached conduit (up to the first support away from the unit).

There are no GERS for Air Compressors

8.2.6.1 *Reference Spectrum Caveats - Air Compressors*

The *Reference* Spectrum (*R*S) represents the seismic capacity of an Air Compressor (AC) if the compressor meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

AC/*R*S Caveat 1 - Earthquake Experience Equipment Class. The air compressor should be similar to and bounded by the AC class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

AC/*R*S Caveat 2 - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the compressor.

Figure 8.2.6-1 Air Compressors from the Earthquake Experience Database

8.2.7 MOTOR-GENERATORS[7]

The seismic capacity for the equipment class of Motor-Generators (MG) *(see Figure 8.2.7-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes motors and generators that are coupled into a motor-generator set (M-G set). Motor-generator sets are structurally similar to horizontal pumps, which consist of an electric motor connected to a pump through a shaft. Motor-generators are basically two motors connected through a common shaft. M-G sets normally include either an AC or DC motor attached through a direct drive shaft to an AC or DC generator. A large flywheel is often mounted at one end of the shaft for storage of rotational inertia, to prevent transient fluctuations in generator output. Usually, both the motor and generator in an M-G set are mounted to a common drive shaft and bolted to a steel skid. Smaller sets sometimes house the motor and generator within the same casing. Motor-generator sets typically range in weight from about 50 to 5000 pounds.

The motor, generator, flywheel, and attached conduit are included in the Motor-Generator equipment class.

There are no GERS for Motor-Generator sets.

8.2.7.1 *Reference Spectrum Caveats - Motor-Generators*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Motor-Generator (MG) if the motor-generator meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

MG/*R*S Caveat 1 - Earthquake Experience Equipment Class. The motor-generator should be similar to and bounded by the MG class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

MG/*R*S Caveat 2 - Driver and Driven Component on Rigid Skid. The main driver and the driven component should be connected by a rigid base or common skid. The concern is that differential displacement between the driver and the driven component may bind the shaft or lead to excessive bearing wear. If they are not mounted on a rigid skid, the potential for differential displacement between the main driver and the driven component should be specially evaluated.

MG/*R*S Caveat *3* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the motor-generator.

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[7] Section B.13 of SQUG GIP (Ref. 1)

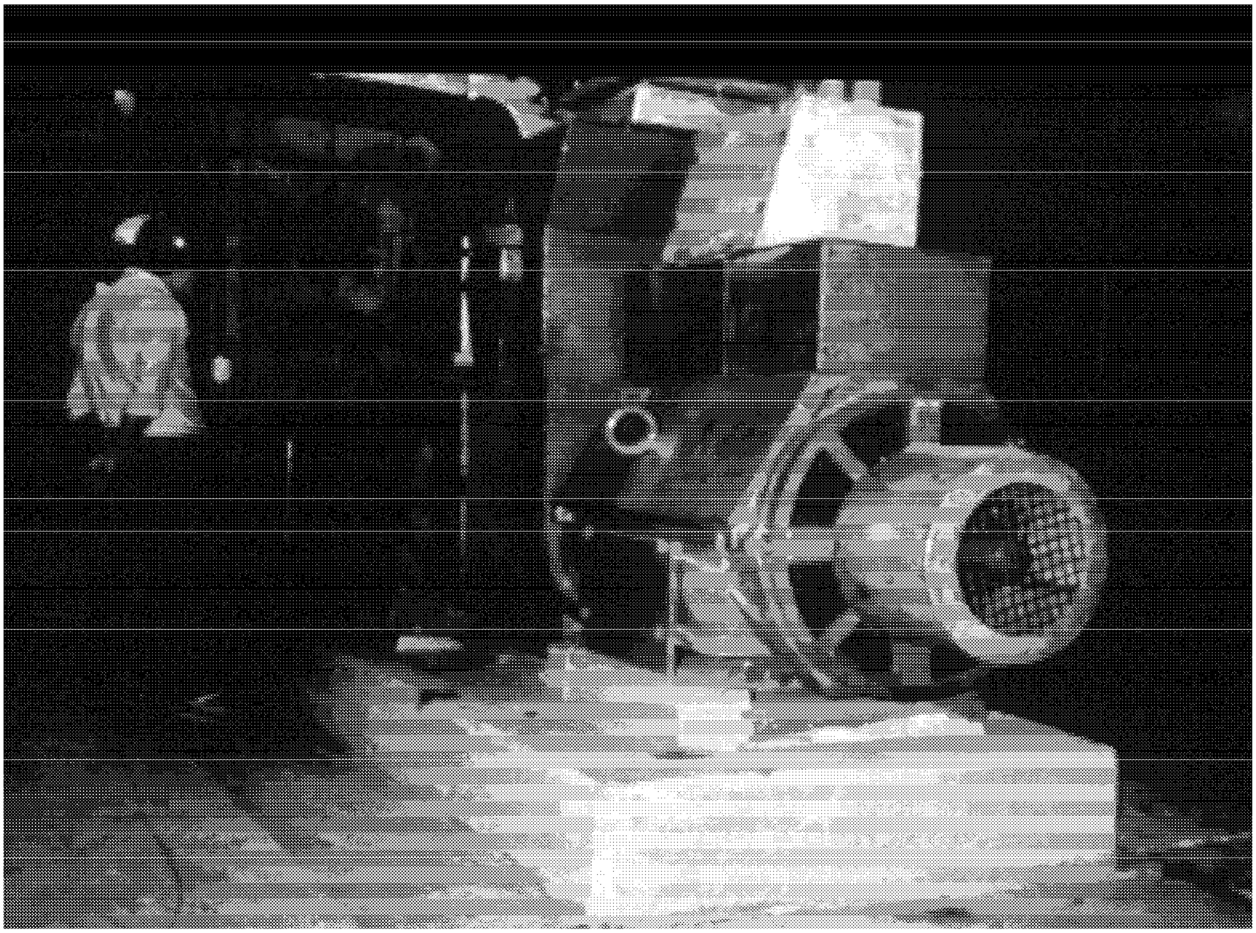

Figure 8.2.7-1 Motor-Generator from the Earthquake Experience Database

8.2.8 ENGINE-GENERATORS[8]

The seismic capacity for the equipment class of Engine-Generators (EG) *(see Figure 8.2.8-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes a wide range of sizes and types of generators driven by piston engines. Turbine driven generators are not *included* in this equipment class. Engine-Generators are emergency power sources that provide bulk AC power in the event of loss of off-site power.

In typical applications, generators range from 200 KVA to 5000 KVA; electrical output is normally at 480, 2400, or 4160 volts. Generators are typically the brushless rotating-field type with either a rotating rectifier exciter or a solid-state exciter and voltage regulator. Reciprocating-piston engines are normally diesel-fueled, although engines may operate on natural gas or oil. In typical applications, piston engines range from tractor-size to locomotive-size, with corresponding horsepower ratings ranging from about 400 to 4000 horsepower.

Engine-generators normally include the piston engine and generator in a direct shaft connection, bolted to a common steel skid. The skid or the engine block also supports peripheral attachments such as conduit, piping, and a local control and instrumentation panel.

The engine-generator system also includes peripheral components for cooling, heating, starting, and monitoring operation, as well as supplying fuel, lubrication, and air. The peripheral components may or may not be mounted on or attached directly to the engine-generator skid. If they are not mounted on the skid, they should be evaluated separately.

There are no GERS for Engine-Generators.

8.2.8.1 Reference Spectrum Caveats - Engine-Generators

The *Reference* Spectrum (*R*S) represents the seismic capacity of an Engine-Generator (EG) if the generator meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

EG/*R*S Caveat 1 - Earthquake Experience Equipment Class. The engine-generator should be similar to and bounded by the EG class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

EG/*R*S Caveat 2 - Driver and Driven Component on Rigid Skid. The driver and the driven component should be connected by a rigid support or common skid. The concern is that differential displacement between the driver and the driven component may bind the shaft or lead to excessive bearing wear. If they are not mounted on a rigid skid, the potential for differential displacement between the driver motor and driven component should be evaluated.

EG/*R*S Caveat *3* - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the generator.

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8 Section B.17 of SQUG GIP (Ref. 1)

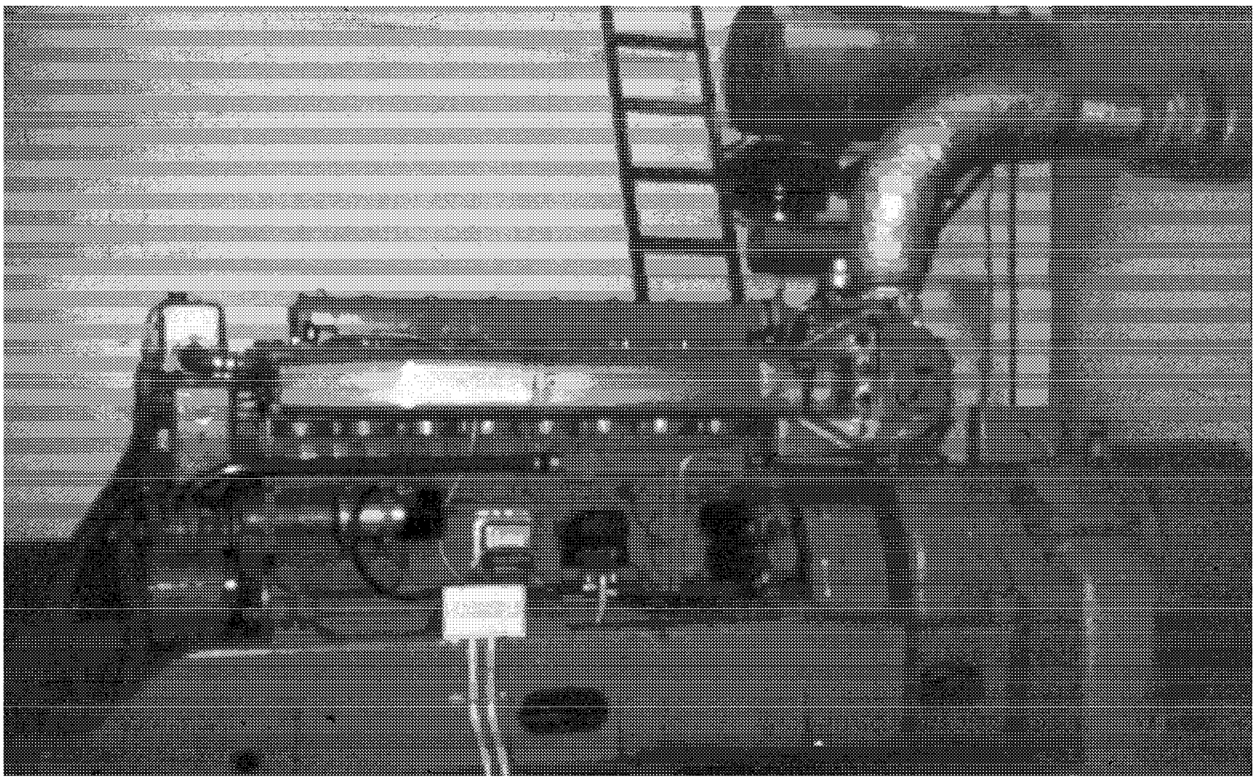

Figure 8.2.8-1 Engine-Generator from the Earthquake Experience Database

8.2.9 AIR HANDLERS[9]

The seismic capacity for the equipment class of Air Handlers (AH) *(see Figure 8.2.9-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes sheet metal enclosures containing (as a minimum) a fan and a heat exchanger. Air handlers are used for heating, dehumidifying or chilling, and distributing air.

The basic components of an air handler include a fan and a coil section. Small capacity, simple air handlers are often referred to as fan-coil units. Additional components such as filters, air-mixing boxes, and dampers are included in more elaborate air handlers. Fans (normally centrifugal) produce air flow across the coil for heat transfer. Coils act as heat exchangers in an air handler. Cooling coils are typically rectangular arrays of tubing with fins attached. Filters are typically mounted in steel frames which are bolted together as part of a modular system. Mixing boxes are used as a plenum for combining two airstreams before channeling the resulting blend into the air handler unit. Dampers are rotating flaps provided in the inlet or outlet sides of the air handler to control the flow of air into or out of the fan.

Air handlers are typically classified as being either a draw-through or a blow-through type. Draw-through air handlers have the heat exchanger (coil) upstream of the fan, whereas the blow-through design locates the coil downstream. Air handler enclosures normally consist of sheet metal welded to a framework of steel angles or channels. Typical enclosures range in size from two feet to over ten feet on a side, with weights ranging from a few hundred pounds to several thousand pounds. Large components, such as fans and coils, are typically bolted to internal frames which are welded to the enclosure framing. Fans may be located in a variety of orientations with respect to the coil unit.

Air handlers typically include a system of attached ducts which provide for the intake and discharge of air. Additional attachments to air handlers include piping and cooling water or refrigerant, electrical conduit, and instrumentation lines. Self-contained air conditioning units are a variation of air handlers, in which the sheet metal enclosure includes a small refrigeration unit. Note that large centralized chillers are addressed as a separate equipment class.

Air handler configurations range from large floor-mounted units to smaller units suspended on rod hangers from ceilings. The sheet metal enclosure, fans and motors, heat exchanger coils, air filters, mixing boxes, dampers, attached ducts, instrument lines, and conduit are included in the Air Handler equipment class.

There are no GERS for Air Handlers.

8.2.9.1 *Reference Spectrum Caveats - Air Handlers*

The *Reference* Spectrum (*R*S) represents the seismic capacity of an Air Handler (AH) if the air handler meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

AH/*R*S Caveat 1 - Earthquake Experience Equipment Class. The air handler should be similar to and bounded by the AH class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

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[9] Section B.10 of SQUG GIP (Ref. 1)

AH/*R*S Caveat 2 - Anchorage of Internal Component. In addition to reviewing the adequacy of the unit's base anchorage, the attachment of heavy internal equipment of the air handler must be assessed. *SCEs* may exercise considerable engineering judgment when performing this review. Internal vibration isolators should meet the requirements for base isolators in *Chapter 6*.

AH/*R*S Caveat 3 - Doors Secured. All doors should be secured by a latch or fastener. The concern addressed by this caveat is that the doors could open during an earthquake, and the loose door could repeatedly impact the housing and be damaged or cause internal components such as relays to malfunction or chatter. In addition, the door may act as an integral structural member and may need to be latched to provide both stiffness and strength to the unit.

AH/*R*S Caveat 4 - No Possibility of Excessive Duct Distortion Causing Binding or Misalignment of Internal Fan. If the air handling unit contains a fan, then the possibility of excessive duct distortion during an earthquake should be considered for its effect on binding or misalignment of the fan. This need only be considered in cases of long unsupported ducts near the air handling unit or relatively stiff ducts subjected to significant relative motion. A special evaluation should be conducted to evaluate for this failure mode if these conditions are considered to be significant by the *SCEs*.

AH/*R*S Caveat 5 - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the air handler.

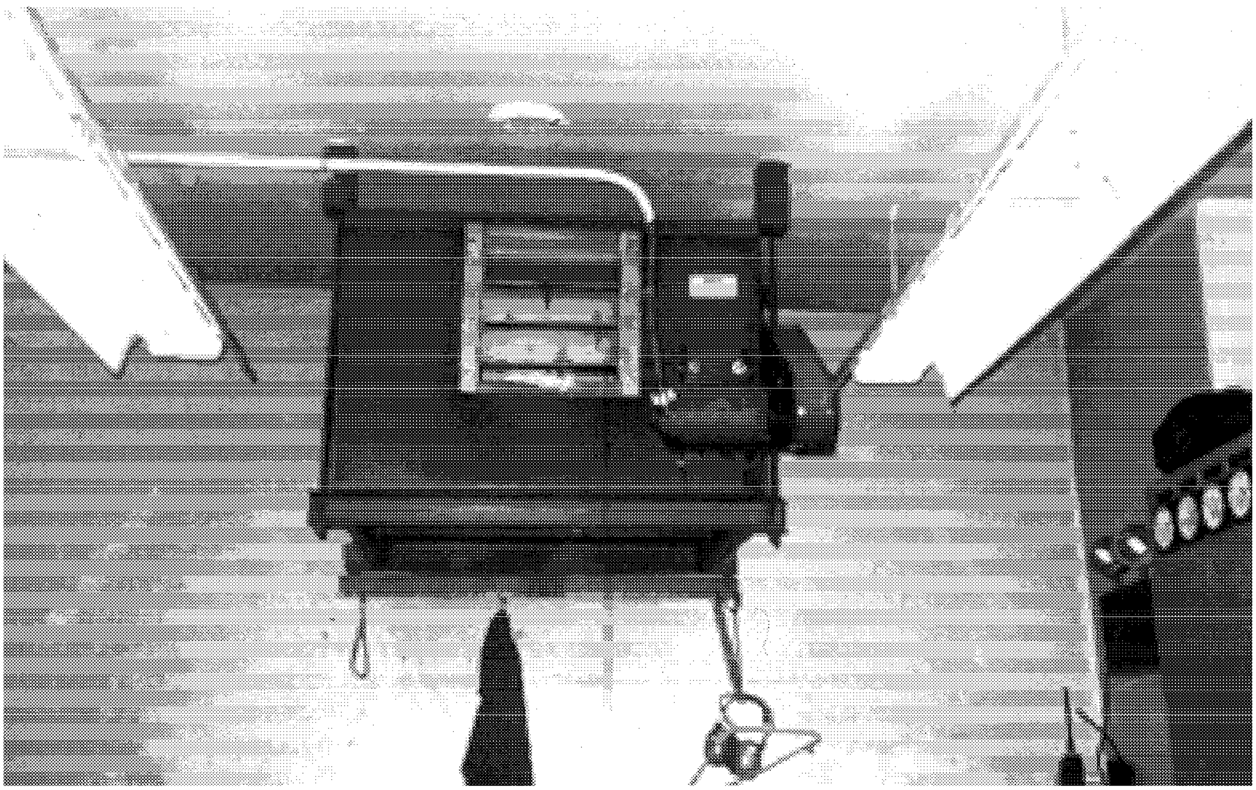

Figure 8.2.9-1 Air Handler from the Earthquake Experience Database

8.2.10 FANS[10]

The seismic capacity for the equipment class of Fans (FAN) *(see Figure 8.2.10-1) may be* based on earthquake experience data, provided the intent of each of the caveats listed below is met. This equipment class includes both freestanding and duct-mounted fans. Fans that are components of other classes of equipment such as air handlers are handled by other respective equipment classes and need not be specifically evaluated here. Blowers and exhausters are included in this equipment class.

Typical differential pressures for fans range from 1/2 inch to 5 inches of water. Some centrifugal fans can have differential pressures ranging up to 12 inches of water. Air flow rates typically range from less than 1000 cubic feet per minute (cfm) to flows on the order of 50,000 cfm. Corresponding fan drive motors typically range from 1 hp to 200 hp. Typical weights of fan units range from 100 to 1000 pounds, depending on capacity and design details. The two basic types of fans in this equipment class include axial fans and centrifugal fans.

Axial fans are used in relatively low pressure applications such as building HVAC systems or cooling towers. Propeller fans and vane-axial fans are the two major types of axial fans. Propeller axial fans consist of two or more blades assembled on a central shaft and revolving within a narrow mounting-ring. Propeller fans are often mounted to a wall or ceiling. Vane-axial fans have an impeller wheel, typically with four to eight blades, mounted to a central shaft within a cylindrical casing. Vane-axial fans are generally used in higher pressure, higher flow applications than propeller fans. Vane-axial fans include a set of guide vanes mounted either before or after the impeller that streamline the air flow for greater efficiency. A variation of vane-axial design is the tube-axial fan, which includes the higher pressure impeller wheel mounted within a cylindrical casing, but without the provision of vanes.

Certain axial fan designs include multiple impellers for increased pressure boost. Axial-flow fans are normally mounted inside cylindrical ducting, supported by radial struts running from the duct wall to the duct centerline. Electric drive motors are usually mounted along the duct centerline immediately upstream of the impeller. The impeller and drive shaft are normally cantilevered from the motor. Alternate designs mount the motor on the outside of the duct with a belt connection between the motor and the impeller drive shaft.

Centrifugal fans are divided into three major categories depending upon the position of their blades. The three blade positions are: forward-curved, radial, and backward-inclined. Forward-curved centrifugals have blades inclined toward the direction of rotation at the tip. These fans produce high flow volumes at low static pressures. Radial-blade centrifugals have their blades positioned on the radii extending from their axis of rotation. Backward-inclined fans are a type of centrifugal fan and have their blades inclined opposite to the direction of rotation at the tip.

Centrifugal fans typically have a cylindrical intake duct centered on the fan shaft and a square discharge duct directed tangentially from the periphery of the fan. A variation of the centrifugal fan is the tubular centrifugal fan which redirects the discharged air in the axial direction. As with axial-flow fans, centrifugal fans can have the electrical drive motor mounted either directly on the fan shaft, or outside of the fan casing with a belt drive to the fan. The impeller and drive shaft may have either a single-point support, where they are cantilevered from the motor, or a two-point support, where the shaft is supported both at the motor and at an end bearing.

The fan impeller and its enclosure, drive motor, attached ducting, mounted louvers, and attached conduit and instrumentation lines are included in the Fan equipment class.

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[10] Section B.9 of SQUG GIP (Ref. 1)

There are no GERS for Fans.

8.2.10.1 *Reference Spectrum Caveats - Fans*

The *Reference* Spectrum (*R*S) represents the seismic capacity of a Fan (FAN) if the fan meets the intent of the following inclusion and exclusion rules. Note, however, that when the specific wording of a caveat rule is not met, then a reason for concluding that the intent has been met should be provided on the SEWS.

FAN/*R*S Caveat 1 - Earthquake Experience Equipment Class. The fan should be similar to and bounded by the FAN class of equipment described above. The equipment class descriptions are general and the *SCEs* should be aware that worst case combinations of certain parameters may not be represented in the generic equipment class. These worst case combinations may have reduced seismic capacity and should be carefully evaluated on a case-by-case basis.

FAN/*R*S Caveat 2 - Drive Motor and Fan Mounted on Common Base. The driver and fan should be connected by a common base or attached in a way to limit differential displacement. The concern is that differential displacement between the driver motor and fan may cause shaft misalignment. If the driver motor and fan are not mounted on a common base, then the potential for differential displacement should be specially evaluated.

FAN/*R*S Caveat 3 - Long Shafts Should be Supported at Fan and at Motor. Axial fans with long shafts between the motor and fan should have the shaft supported at the fan and at the motor. The concern is shaft misalignment. If the shaft is not supported in both locations, then a special evaluation should be conducted. The potential earthquake displacement of the shaft should be determined and compared to the operability displacement limits of the fan.

FAN/*R*S Caveat 4 - No Possibility of Excessive Duct Distortion Causing Binding or Misalignment of Fan. The possibility of excessive duct distortion during an earthquake should be considered for its effect on binding or misalignment of the fan. This need only be considered in cases of long unsupported ducts near the fan or relatively stiff ducts subjected to significant relative support motion. A special evaluation should be conducted to evaluate for this failure mode if these conditions are considered to be significant by the *SCEs*.

FAN/*R*S Caveat 5 - Any Other Concerns? *SCEs* should seek out suspicious details or uncommon situations not specifically covered by the caveats which could adversely affect the seismic capacity of the fan.

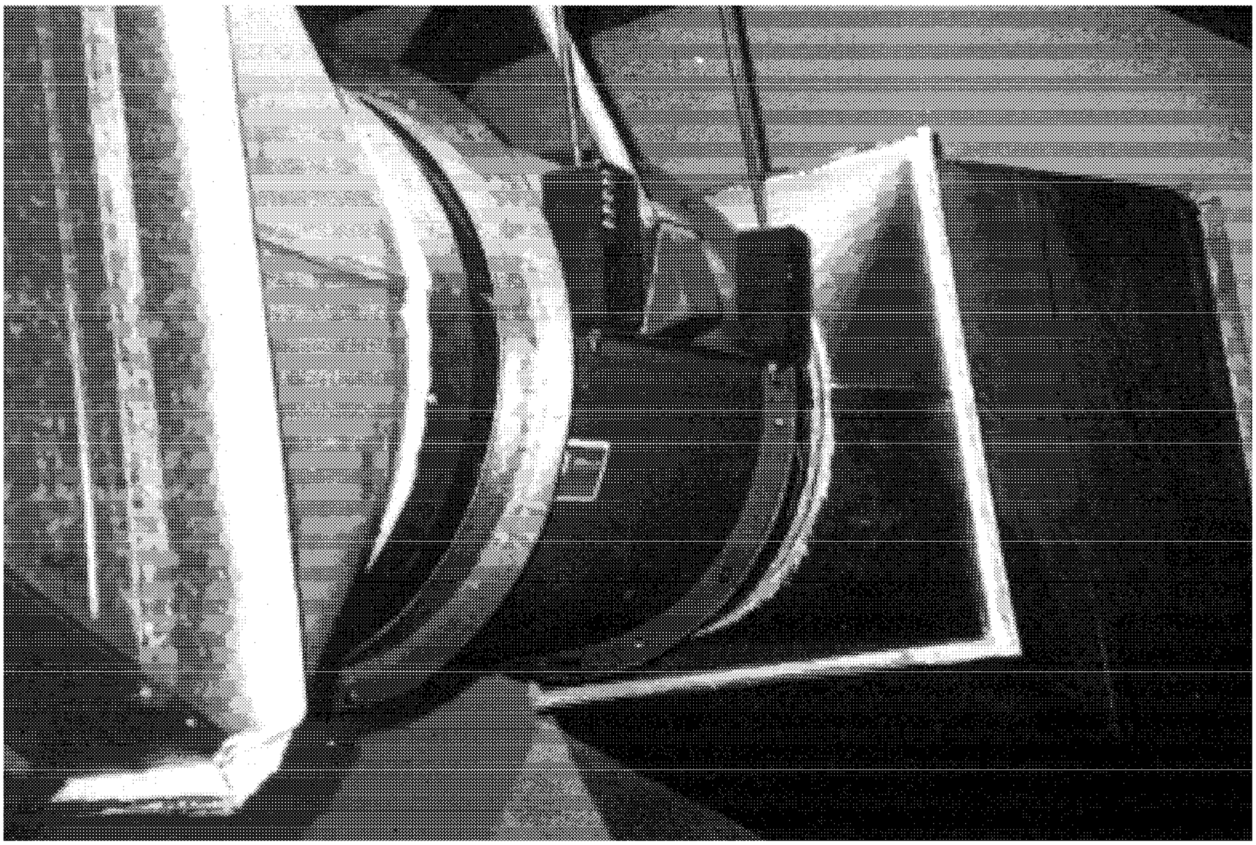

Figure 8.2.10-1 Fan from the Earthquake Experience Database